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MANNED EVALUATION OF THE NCSC DIVER THERMAL PROTECTION (DTP) PA--ETC(U)
AUG 79 C A PIANTADOSI, D J BALL, M L NUCKOLS

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DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
Panama City, Florida 32407

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NAVY EXPERIMENTAL DIVING UNIT
REPORT NO. 13-79

MANNED EVALUATION OF THE NCSC DIVER THERMAL PROTECTION (DTP) PASSIVE SYSTEM PROTOTYPE.

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Twenty-eight, long duration, manned, air dives were performed at the Navy Experimental Diving Unit in 35 - 42°F (1.7 - 5.6°C) water and depths of 10 FSW and 70 FSW to evaluate the effectiveness of the NCSC Diver Thermal Protection (DTP) Passive System Prototype. Measurements used to establish rates of heat loss in divers wearing the DTP prototype included body core temperature, mean skin temperature, and mean body convective heat loss. These measurements were compared with currently accepted physiological criteria

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for thermal exposures in divers to obtain guidelines for use of the system.

Results indicated that the DTP Passive System Prototype can safely support a working diver for up to six hours, and a resting diver for up to three hours, in 35 - 42°F (1.7 - 5.6°C) water. Depth dependent degradation of suit performance was not observed, as suit insulation averaged 1.0 clo at both test depths. Attempts by cold resting divers to rewarm themselves with intermittant leg exercise were sometimes associated with a small body core temperature afterdrop which could be overcome by continued exercise. Problems requiring additional design and test effort were encountered with inadequate thermal protection of the extremities, particularly the hands, and inadequate sealing of the dry suit outergarment.

ABSTRACT

Twenty-eight, long duration, manned, air dives were performed at the Navy Experimental Diving Unit in 35 - 42°F (1.7 - 5.6°C) water and depths of 10 FSW and 70 FSW to evaluate the effectiveness of the NCSC Diver Thermal Protection (DTP) Passive System Prototype. Measurements used to establish rates of heat loss in divers wearing the DTP prototype included body core temperature, mean skin temperature, and mean body convective heat loss. These measurements were compared with currently accepted physiological criteria for thermal exposures in divers to obtain guidelines for use of the system.

Results indicated that the DTP Passive System Prototype can safely support a working diver for up to six hours, and a resting diver for up to three hours, in 35 - 42°F (1.7 - 5.6°C) water. Depth dependent degradation of suit performance was not observed, as suit insulation averaged 1.0 clo at both test depths. Attempts by cold resting divers to rewarm themselves with intermittant leg exercise were sometimes associated with a small body core temperature afterdrop which could be overcome by continued exercise. Problems requiring additional design and test effort were encountered with inadequate thermal protection of the extremities, particularly the hands, and inadequate sealing of the dry suit outergarment.

Introduction

Regional and whole body hypothermia is a major factor affecting diver comfort, performance, and safety in operational cold water diving. This problem is primarily due to the ability of water to conduct heat away from the human body 25 times faster than air. In addition, the heat capacity of water (product of density and specific heat) exceeds that of air by some 3500 times. These physical properties of water can result in a net heat loss from the body of an unprotected diver in water temperatures as warm as 90°F (32.2°C), depending upon body surface area, mass, subcutaneous fat, and level of activity (1).

Traditionally, passive thermal insulation for the diver has taken one of two forms; either thermal underwear covered by a dry suit, or a closed-cell foam rubber wet suit. Dry suits usually provide satisfactory thermal protection for most cold water diving situations, but they often limit diver mobility and are subject to leakage. Wet suits provide greater mobility and adequate thermal protection for shallow, short duration, cold water dives. However, closed-cell foam is compressed significantly as hydrostatic pressure increases, resulting in marked degradation of insulation value with depth (2).

For long duration or deep cold water dives, the design of an effective dry suit coupled with an adequate thermal undergarment is essential for diver safety. The development of such a passive dry suit system for use by the U.S. Navy has been undertaken at the Naval Coastal Systems Center (NCSC) in Panama City, Florida. The prototype system, known as the Diver Thermal Protection (DTP) Passive System, consists of a compression-resistant undergarment and elastomeric-coated fabric dry suit outergarment.

Unlike conventional foam dry suits, the DTP prototype derives its major thermal insulation from the undergarment with the outergarment serving only as a water barrier. The absence of closed-cell foam rubber minimizes the degradation of thermal suit insulation with depth as illustrated in Figure (1).

A comparative evaluation of prospective thermal undergarments performed at NCSC resulted in the selection of a prototype constructed primarily of a fine, synthetic fiber material known as M-400 Thinsulate (3-M Corporation) shown in Figure (2). The insulation characteristics of this material are summarized elsewhere (3).

Two prototypes for the DTP passive system outergarment are still under consideration. These consist of a crushed neoprene foam dry suit, and a rubber-coated polyester stretch fabric dry suit. Both suits are designed to maintain the water-tight integrity of the DTP system, and do not otherwise affect the insulation of the undergarment.

Necessary suit accessories such as dry gloves, supply and exhaust valves for adequate buoyancy control, and a urine collection device for long duration dives are also under development. The DTP passive system is intended to provide adequate thermal protection for up to 95% of all Navy diving missions. In particular, the system is designed to support a diver for up to six hours in 35°F water under all air mode diving conditions. For surface-supplied mixed gas and saturation diving, supplemental heating (active DTP system) is to be added to the passive suit system.

In order to evaluate the ability of the DTP passive system prototype to meet its design criteria, 28 long duration manned air dives were performed at

the Navy Experimental Diving Unit in 35-42°F (1.7-5.6°C) water at depths of 10 FSW and 70 FSW. All studies were performed under exercise conditions consistent with operational cold water air diving, and the thermal adequacy of the DTP passive system was evaluated against accepted thermal physiological criteria.

Methods

The dive series consisted of twelve 120 to 180 minute air dives by four subjects at 10 FSW, and sixteen 180 minute air dives by eight additional subjects at 70 FSW. The physical characteristics of the diving personnel who participated in these dives are shown in Table (1).

The 10 FSW dive series was performed in the test pool at the Navy Experimental Diving Unit. Water temperature was 40 ± 2°F for this series of studies and the diving apparatus was the U.S. Navy Mark 1 Mod 0 Bandmask. The 70 FSW dive series was performed in the wet pot of the Ocean Simulation Facility during a five day air saturation dive. Wet pot water temperature was maintained at 35 to 36°F (1.7 to 2.5°C). The diving apparatus was an AGA full facemask and demand regulator (AGA Spiro, Lidingo, Sweden) with a harness fitted with a low pressure manifold and air umbilical air supply. The use of the AGA mask during the 70 FSW dives was prompted by excess positive buoyancy of the passive system when used with the MK 1 mask. The MK 1 mask had necessitated the use of excessive weight which limited the ability of the diver to inflate the dry suit during the 10 FSW dive series.

Subjects were instrumented with a heat flow belt system consisting of twelve heat flow/temperature transducers (Thermonetics, Inc.) as well as a rectal probe (YSI 700 series) inserted 15 cm into the rectum. Heat flow

transducer placement was as shown in Fig. 3 and were fixed in place with Dressinet surgical netting (Diffusan, Inc.). All twelve heat flow and temperatures were monitored at 2 min intervals with an HP 21 MX computer as described elsewhere (4). Mean convective heat flow ($\bar{H}_c$), mean skin temperature ($\bar{T}_s$), mean body temperature ($\bar{T}_{BT}$), thermal insulation of the DTP suit ($\bar{C}_{Bs}$), and change in body heat content (Δ S), were calculated as outlined in Appendix A.

The thermistors incorporated into these sensors were similar to those shown to be little affected by pressurization and depressurization to pressures of 71 ATA in helium (5). Similar evidence for use of heat flow transducers under pressure has recently been reported by one of us (6). In addition, calibration factors for each of the heat flux transducers were measured prior to use as described elsewhere (7).

Once the subject was instrumented, he donned the DTP passive prototype system over the heat flow transducers. This system consisted of Long-John underwear, wool socks, M-400 Thinsulate undergarment including double insulation boots, variable volume dry suit and dry gloves, and a U.S. Navy Integrated Diving Vest (NSN-H422001-045-2194) with backpack removed and weight adjusted for each diver. Air volume in the dry suit was adjusted by the diver for comfort during each dive.

The test series was divided into three parts. Part 1 consisted of 150 min of rest, followed by up to 30 min of moderate intermittant exercise. Part 2 consisted of approximately 3 hours of intermittant moderate exercise, and Part 3 consisted of three intermittant periods of exercise ranging from moderate to heavy, followed by a long rest period. Part 1 was designed to evaluate cold diver rewarming after a long period of inactivity. Part 3 was designed to investigate the effects of a sudden cessation of exercise after an

initial warming period induced by heavy exercise. Part 3 was not performed at 70 FSW because no significant differences in body cooling between Parts 1 and 3 were observed at 10 FSW. All exercise was performed on a Collins, electrically-braked, pedal mode ergometer modified for use underwater (8). Exercise protocols for each experimental sequence were as shown in Table (2).

Maximum duration for all studies was 180 minutes. The experiment was terminated if rectal temperature reached 35.5°C or if suit flooding occurred. In addition, the diver could end the study at his option if discomfort became intolerable.

Results

Table (3) summarizes the results of the DTP passive system evaluation at 10 FSW and shows the net changes in parameters over the total time of the study divided by the study time in hours. The computations began after 30 minutes of cold water immersion to minimize the effect of peripheral vasoconstriction on net thermal balance calculations. Diver #1 flooded his dry suit through the neck seal 56 minutes into the resting study, and this data was excluded from the results. During rest, mean decrease in rectal temperature (T_R) in the other three subjects was 0.4 ± 0.1°C per hour, and decrease in $\bar{T}_s$ was 2.9 ± 0.7°C per hour. Mean decrease in body heat content (S) was 87 ± 22 Kcal per hour, and mean suit insulation value ($\bar{C}_{Bs}$) was 1.2 ± 0.2 clo. There was no significant difference in the rate of cooling between rest (Part 1) and heavy work followed by prolonged rest (Part 3). The divers were unable to reach thermal equilibrium in either experiment, in spite of exposures up to 180 minutes and continuous shivering.

During the moderate intermittant work study (Part 2) at 10 FSW (Table 3), three of four subjects reached thermal equilibrium after two to three hours. Diver #1 did not reach equilibrium because he again had difficulty with a small amount of water leakage around his neck seal. Mean decrease in body heat content was reduced to 48 $\pm$ 30 Kcal per hour by exercise. Mean insulation value was 1.0 $\pm$ 0.1 clo; not significantly different from values obtained during the other two parts of the 10 FSW study. Graphs of $\bar{T}_s$ and T_R versus time for all three parts of this study are presented in Figures (4) and (5). Note that the last 30 min of Part 2, the period of exercise, is not shown in the above figures.

Table (4) summarizes the results of the DTP passive system evaluation at 70 FSW. The net changes shown again begin 30 min after the start of each study. Diver #8 developed suit flooding 42 min into his intermittant, moderate work dive, and this dive was excluded from the results. During rest, mean decrease in rectal temperature (T_R) was 0.5 $\pm$ 0.2°C per hour, and decrease in $\bar{T}_s$ was 1.8 $\pm$ 0.7°C per hour. The rate of change in $\bar{T}_s$ at 70 FSW was 1.1°C per hour less than at 10 FSW. This may have been due to the ability of the subjects to inflate the dry suits with larger volumes of air during the 70 FSW dive series because less positive buoyancy was contributed to the system by the AGA face mask than by the MK 1 mask used in the 10 FSW dive series. However, during rest, mean suit insulation value at 70 FSW was 1.0 $\pm$ 0.2 clo, which was not significantly different than mean insulation at 10 FSW. The lower rates of change in $\bar{T}_{BT}$ and therefore smaller changes in body heat content than at 10 FSW. Mean decrease in body heat content at 70 FSW was 58 $\pm$ 20 Kcal per hour during resting dives.

During moderate, intermittant work at 70 FSW (Table 4), all eight divers reached thermal equilibrium before three hours. Mean decrease in body heat content during this part of the study was only 28 $\pm$ 11 Kcal per hour, and $\bar{T}_R$ remained essentially unchanged. Mean suit insulation ($\bar{C}_{BS}$) was unchanged from insulation at rest, and was the same as during the 10 FSW dives. Graphs of $\bar{T}_s$ and T_R versus time for both parts of the 70 FSW study was presented in Figures (6) and (7).

During rest, (Part 1) at 70 FSW, most divers reported the onset of intermittant shivering after 60 to 90 minutes, and several divers experienced uncontrollable shivering during rest after 90 to 120 minutes. Mean convective heat flow ($\bar{H}_c$) at 70 FSW for resting dives was 360 $\pm$ 29 Kcal per hour, and the change in body heat content (ΔS) was 58 Kcal/hr. Assuming that 1 liter of O_2 is equivalent to 4.9 Kcal (13), then the difference between the rate of convective heat loss and decrease in body heat content represents an oxygen consumption ($\dot{V}_{O_2}$) of 1.05 l/min. This estimate does not account for radiative, evaporative, or respiratory heat loss by the diver.
A similar estimate for moderate, intermittant work was not made because of lack of an accurate assessment of the mechanical efficiency of pedalling underwater.

During the two dives where complete outgarment flooding occurred high rates of heat loss were recorded from the subject's skin. After the water inside the suit was warmed by this heat flow, convective heat loss decreased to levels near those recorded while the suit was dry. Suit insulation remained in the 0.7 clo range after restabilization.

Problem areas reported by the dive subjects centered around the outergarment. Difficulty in donning the suit was encountered, particularly for the unassisted diver to penetrate the foam neck seal and flatten it out

around his neck. Inadequate neck sealing resulted in gradual influx of water into the suit. Other problems were encountered with inadequate dry glove sealing, and several gloves flooded at depth. Even with dry gloves, most divers reported cold hands and subjectively decreased manual dexterity. Skin temperatures on the dorsal surface of the hand frequently reached 12°C to 15°C even during exercise. In addition, divers commonly complained of cold feet in spite of double insulation boots, and foot temperature fell below 15°C during two of the 70 FSW dives.

During the last 30 minutes of the resting dives at 70 FSW, intermittant work at 75 watts on the underwater ergometer (Table 2) was performed to determine the ability of the cold diver to rewarm himself with exercise. Six subjects completed this exercise schedule; one diver terminated his resting study at 120 minutes because of shivering, and one study was terminated at 146 minutes because of technical problems. Five of the six divers completing the work schedule showed an initial fall in rectal temperature averaging 0.2°C during the first ten minutes following the onset of work. With further exercise, there was a gradual increase in rectal temperature accompanied by an increase in mean skin temperature. This phenomenon is illustrated in Figure (8). The other subject showed rapid stabilization of body core temperature with the onset of exercise, followed by gradual increases in core and mean skin temperatures.

Discussion

Currently available physiological criteria for diver thermal protection in the U.S. Navy specify a maximum net body heat loss not to exceed 200 Kcal, rectal temperature not lower than 36°C, mean skin temperature not lower than

25°C with individual skin temperatures not lower than 20°C except for the hand which may go as low as 15°C, and a metabolic response from shivering not to increase oxygen consumption ($\dot{V}_{O_2}$) more than 0.5 SLPM above the metabolic cost of the diver's activity (9). Although these criteria do not consider rates of body heat loss (10), they provide generally adequate guidelines for assessment of diver thermal protection garments by today's standards.

Comparison of thermal data recorded in divers wearing the DTP Passive System prototype with the above physiological limits indicates that the dry M-400 Thinsulate undergarment provides adequate thermal protection during air diving and conditions of moderate, intermittant work for up to six hours in water as cold as 35°F (1.7°C). Depth dependent degradation of undergarment insulation was not observed between depths of 10 and 70 FSW, and is not anticipated at depths deeper than 70 FSW.

In the resting diver, body core protection is marginal and net body heat loss approaches 200 Kcal after three hours in most subjects at water temperatures less than 42°F (5.6°C). In addition, estimated mean resting oxygen consumption exceeds 1.0 SLPM, which represents a metabolic response from shivering of about 0.5 SLPM. Supplemental heating is required for body core protection during resting, cold water air dives longer than three hours duration. In addition, investigation of the insulation characteristics of the Thinsulate undergarment during complete outer suit flooding is necessary. Nevertheless, the use of this undergarment as added thermal protection when worn under existing, approved dry suits will enhance diver comfort and safety.

During both work and rest, cold (12-15°C) and sometimes painful extremities, along with subjectively decreased manual dexterity, represent major unsolved

problems in the DTP Passive System prototype. The current dry suit configurations [illegible] have unsatisfactory neck seal and dry glove seal characteristics, which allow a gradual influx of cold water in some subjects.

Attempts by cold subjects to rewarm themselves with intermittent leg exercise were sometimes accompanied by initial decreases in rectal temperature (Figure 8). This phenomenon may represent rapid vasodilation of thigh muscle capillaries in response to exercise and subsequent exchange of heat from warm core blood to the initially cooler muscles of the lower extremities. This observation is consistent with the afterdrop phenomenon observed during rewarming of clinical hypothermia victims (11), and similarly reported with leg exercise in a cold dry environment (12). Continued exercise through the afterdrop period resulted in significant increases in body core temperature in all subjects, suggesting rewarming by moderate exercise while wearing the DTP Passive System is possible.

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APPENDIX A: Derived Parameters and Method of Calculation

(1) Mean Convective Heat Flow and Mean Skin Temperature

$$\bar{H}_c = 0.070\ H_1 + 0.085\ H_2 + 0.085\ H_3 + 0.090\ H_5$$

$$+ 0.140\ H_6 + 0.050\ H_7 + 0.095\ H_8 + 0.065\ H_9 + 0.095\ H_{10}$$

$$+ 0.065\ H_{11} + 0.070\ H_{12}$$

where

$\bar{H}_c$ = mean heat flow (watts)

$H_1 - H_{12}$ = heat flows at sensor locations 1 to 12

Mean skin temperature ($\bar{T}_s$) calculated using the same weighting factors and by substituting skin temperatures ($T_1 - T_{12}$) for heat flows in the above equation.

(2) Mean Body Temperature

$$\bar{T}_{BT} = 0.67 T_R + 0.33\ \bar{T}_s$$

where

$\bar{T}_{BT}$ = mean body temperature (°C)

T_R = rectal temperature

$\bar{T}_s$ = mean skin temperature

(3) Mean Suit insulation

$$\bar{C}_{BS} = \frac{\bar{T}_s - T_A}{\bar{H}}$$

where

$\bar{C}_{BS}$ = mean insulation of suit (clo)

T_A = ambient temperature

(4) Change in Body Heat Content

$$\Delta S = 0.83 \cdot \bar{T}_{BT} \cdot M$$

where

ΔS = change in body heat content due to heat losses via conduction, convection, radiation, and respiration.

0.83 = average value of heat capacity of human tissue (Kcal/kg °C)

M = mass of the diver (kg)

$\bar{T}_{BT}$ = change in mean body temperature

APPENDIX B: TABLES AND FIGURES

TABLE (1)

PHYSICAL CHARACTERISTICS OF DIVING SUBJECTS

Subject	Dive Series	Age(years)	Height(cm)	Weight(kg)	Body Surface Area(m^2)	Skin Fold* Thickness (Sum of Three)
1	10 FSW	44	189	87.5	2.10	46
2	10 FSW	35	180	87.6	2.05	40
3	10 FSW	29	178	86.5	2.02	56
4	10 FSW	36	175	78.6	1.95	39
1	70 FSW	35	175	70.9	1.85	22
2	70 FSW	30	175	80.0	1.94	40
3	70 FSW	31	180	83.6	2.02	40
4	70 FSW	33	170	76.8	1.90	52
5	70 FSW	36	178	75.9	1.91	39
6	70 FSW	29	182	79.6	1.98	36
7	70 FSW	27	182	90.0	2.08	48
8	70 FSW	28	178	73.4	1.91	27

*Sum of Skin Fold Thickness Measured at STandard Triceps, Subscapular, and Suprailiac sites.

TABLE (2). EXERCISE PROTOCOLS FOR THE DTP PASSIVE SYSTEM EVALUATION

	Zero Time(minutes)	Work Rate
PART (1)	0 - 150	Rest
	150 - 156	75 Watts
	156 - 160	Rest
	160 - 166	75 Watts
	166 - 170	Rest
	170 - 176	75 Watts
	176 - 180	Rest
PART (2)	0 - 6	50 Watts
	6 - 10	Rest
	10 - 16	50 Watts
	16 - 20	Rest
	Work/rest cycles continued for 180 min or until termination.	
PART (3)	0 - 6	50 Watts
	6 - 10	Rest
	10 - 16	100 Watts
	16 - 20	Rest
	20 - 26	150 Watts
	26 - 180 or termination	Rest

TABLE (3): DTP PASSIVE SYSTEM EVALUATION

10 FSW - Water Temp 38 - 42°F (1.7-5.6°C)

	SUBJECT	ΔT_R (°C/hr)	$\Delta \bar{T}_s$ (°C/hr)	$\Delta \bar{T}_{BT}$ (°C/hr)	ΔS (Kcal/hr)	$\bar{C}_{BS}$ (clo)
PART 1 Rest	1*	---	---	---	---	---
	2	-0.4	-3.7	-1.5	- 112	1.0
	3	-0.3	-2.5	-1.0	- 71	1.1
	4	-0.5	-2.6	-1.2	- 78	1.4
		-0.4 ± 0.1	-2.9 ± 0.7	-1.2 ± 0.3	-87 ± 22	1.2 ± 0.2
PART 2 Moderate Work	1	-0.3	-3.0	-1.2	- 86	0.9
	2	-0.5	-1.3	-0.7	- 53	1.1
	3	-0.0	-0.7	-0.2	- 45	1.0
	4	-0.4	-1.2	-0.6	- 39	1.0
		-0.3 ± 0.2	-1.6 ± 1.0	-0.7 ± 0.4	-48 ± 30	1.0 ± 0.1
PART 3 Heavy work	1	-0.7	-3.3	-1.6	- 112	1.0
	2	-0.3	-2.5	-1.1	- 77	1.0
	3	-0.4	-2.7	-1.2	- 86	0.9
	4	-0.9	-2.5	-1.4	- 91	1.1
		-0.6 ± 0.3	-2.8 ± 0.4	-1.3 ± 0.2	-92 ± 15	1.0 ± 0.1

*Suit flooded 56 minutes into the dive.

TABLE (4): DTP PASSIVE SYSTEM EVALUATION

70 FSW - Water Temperature 35 - 36°F

	Subject	ΔT_R(°C/hr)	$\Delta \bar{T}_s$(°C/hr)	$\Delta \bar{T}_{BS}$(°C/hr)	ΔS(Kcal/hr)	$\bar{C}_{BS}$(clo)	$\bar{H}_c$(Kcal/hr)	Estimated Mean $\dot{V}_{O_2}$(SLPM)
PART 1: Rest	1	-0.8	-1.9	-1.1	-65	1.0	325	0.88
	2	-0.4	-3.1	-1.3	-84	0.9	360	0.94
	3	-0.2	-1.3	-0.6	-38	0.9	390	1.20
	4	-0.3	-1.2	-0.6	-42	1.3	404	1.27
	5	-0.7	-2.2	-1.2	-78	0.8	342	0.90
	6	-0.3	-1.2	-0.6	-36	0.9	354	1.08
	7	-0.5	-1.7	-1.0	-75	1.1	336	0.90
	8	-0.4	-1.4	-0.7	-43	0.8	366	1.10
		-0.5 ± 0.2	-1.8 ± 0.7	-0.9 ± 0.3	-58 ± 20	1.0 ± 0.2	360 ± 29	1.05 ± 15
PART 2: Moderate Work	1	-0.1	-1.5	-0.5	-32	0.9	---	
	2	-0.2	-1.1	-0.4	-27	1.3	390	
	3	-0.0	-0.5	-0.2	-11	0.9	360	
	4	-0.0	-1.6	-0.5	-31	0.9	366	
	5	-0.2	-0.6	-0.3	-20	1.1	300	
	6	-0.0	-1.2	-0.4	-26	1.2	396	
	7	-0.3	-1.5	-0.5	-48	1.0	324	
	8*	---	---	---	---	---	---	
	Mean ± sd	-0.1 ± 0.1	-1.1 ± 0.4	-0.4 ± 0.1	-28 ± 11	1.0 ± 0.2	356 ± 38	

*Suit flooded at 42 min into the dive.

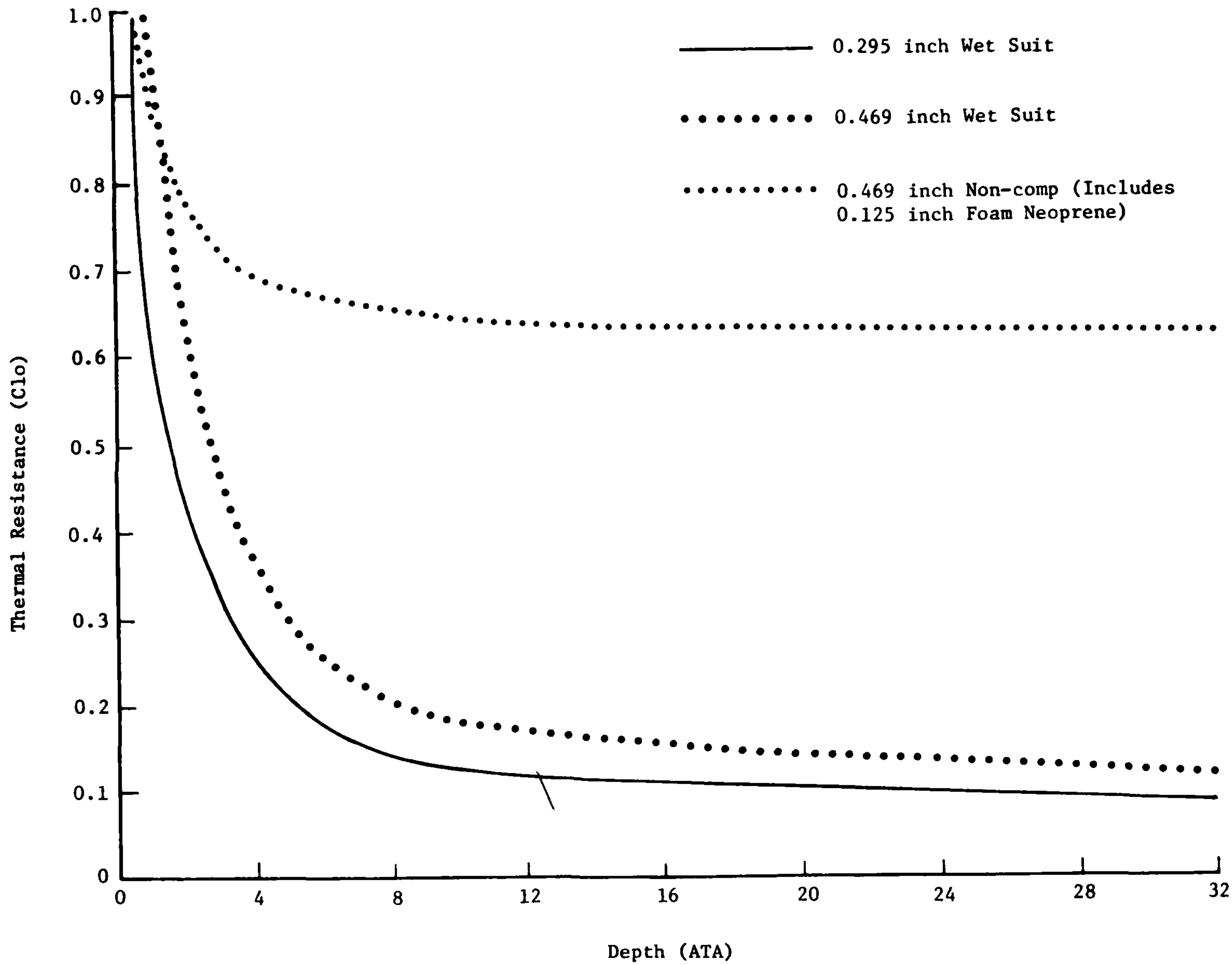


FIGURE 1. Insulation Values of Wet Suits Under Hyperbaric Conditions
(See Reference 2)

FIGURE 2: Prototype M-400 Thinsulate Thermal Undergarment

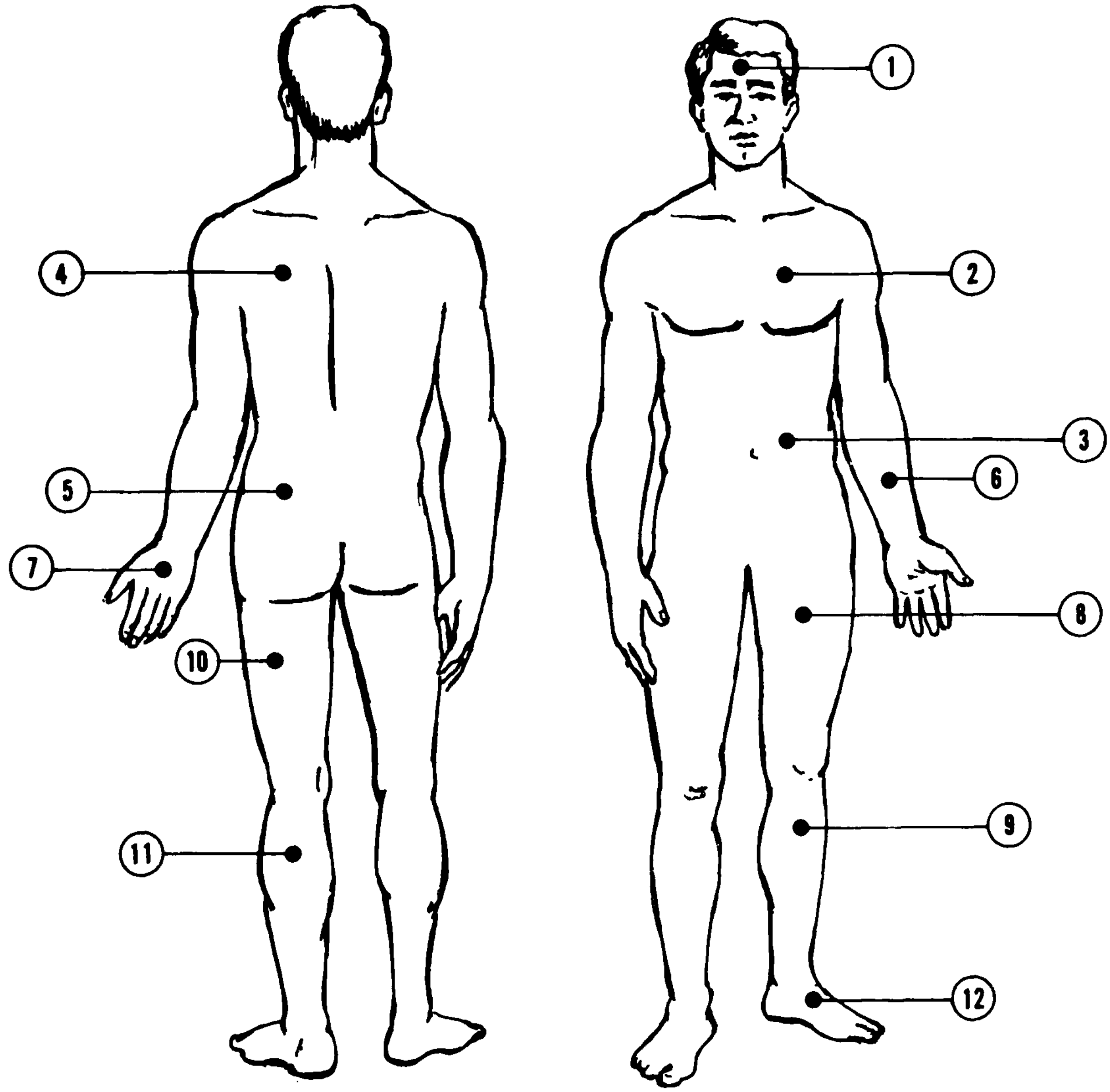


FIGURE 3: Placement of Heat Flow Belt Transducers

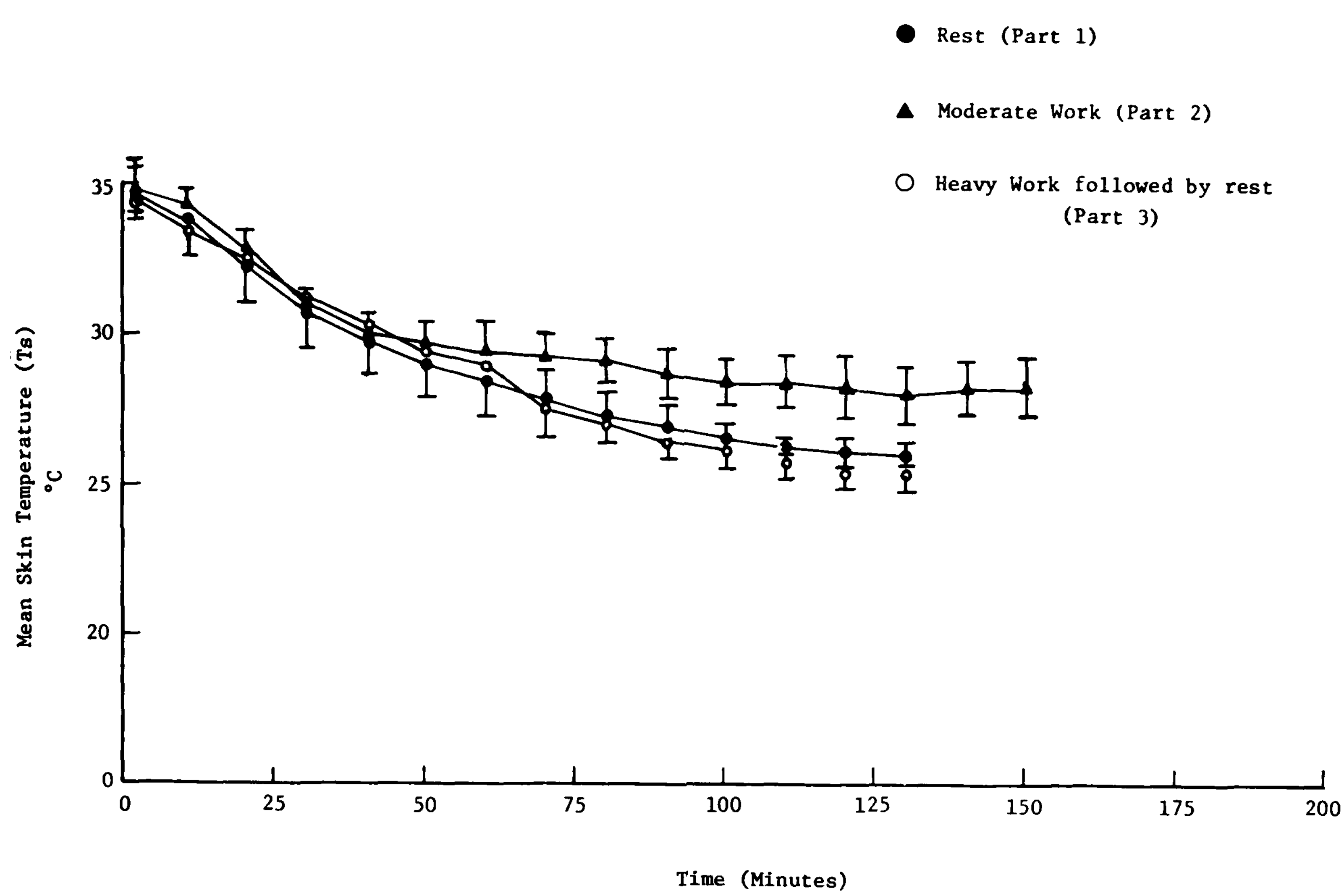


FIGURE 4: Mean Skin Temperature ($\bar{T}_s$) vs Time at 10 FSW and 38-42°C water

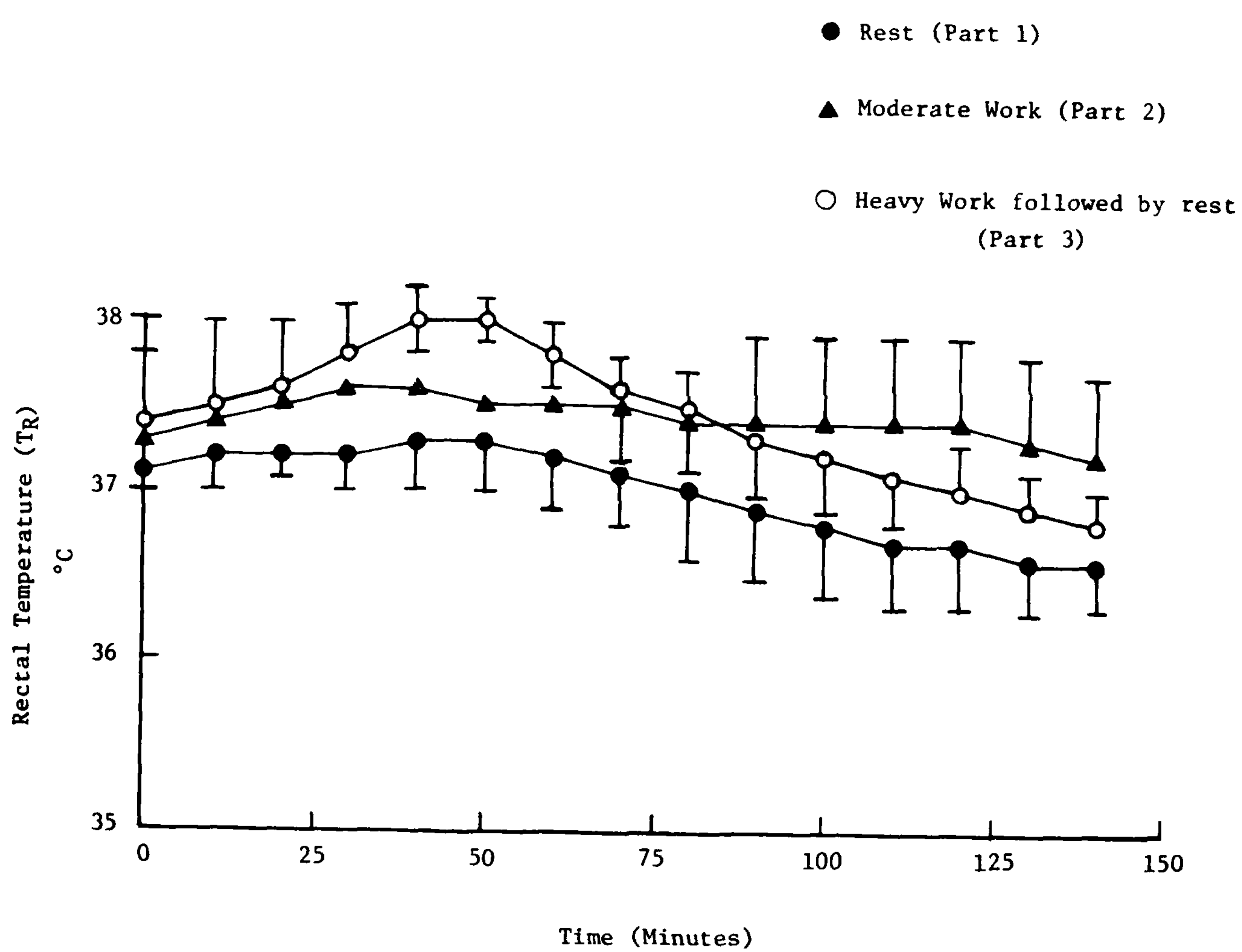


FIGURE 5: Rectal Temperature (T_R) vs Time at 10 FSW and 38-42°C water

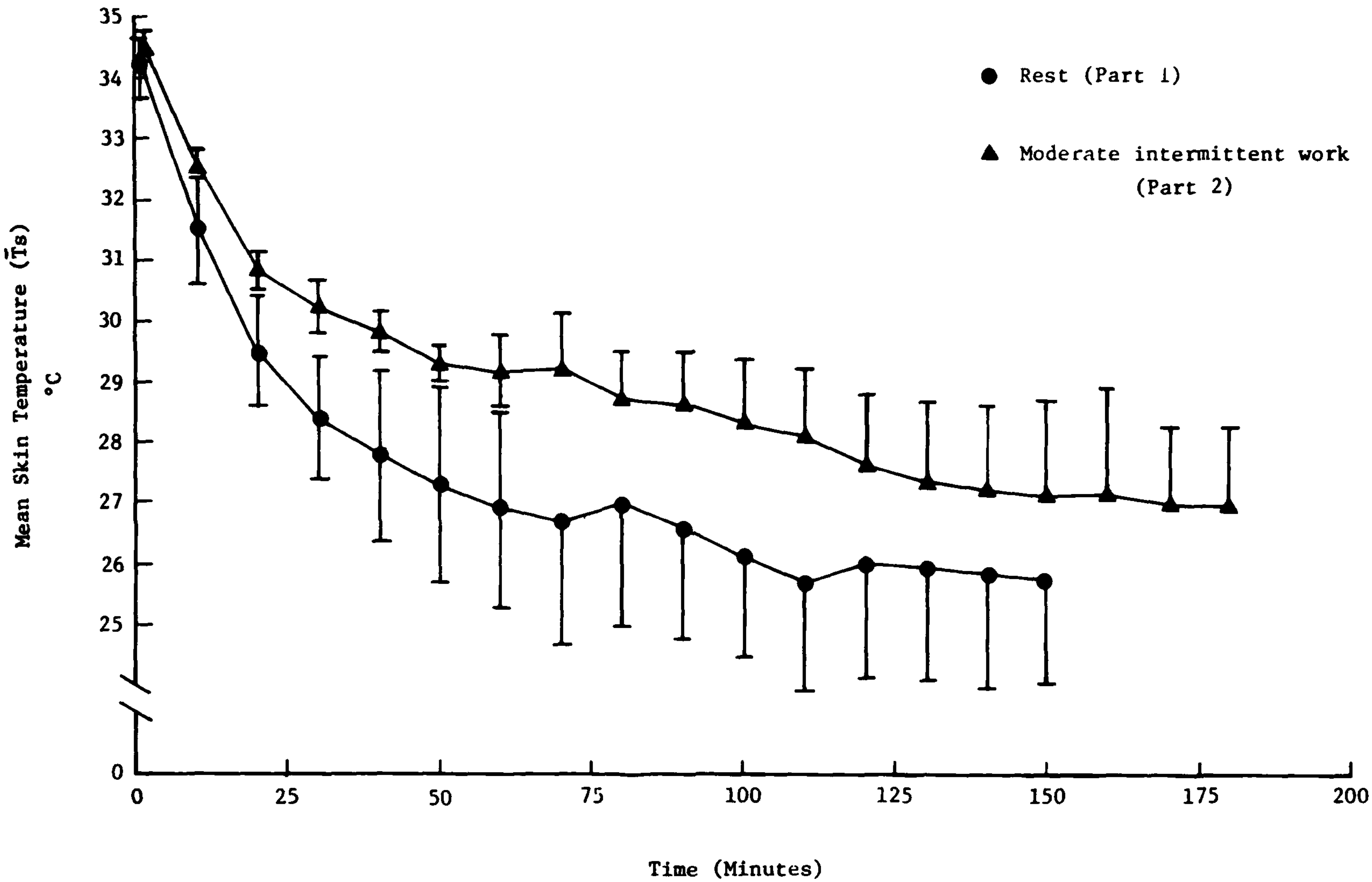


FIGURE 6: Mean Skin Temperature ($\bar{T}_s$) vs Time at 70 FSW and 35°C water

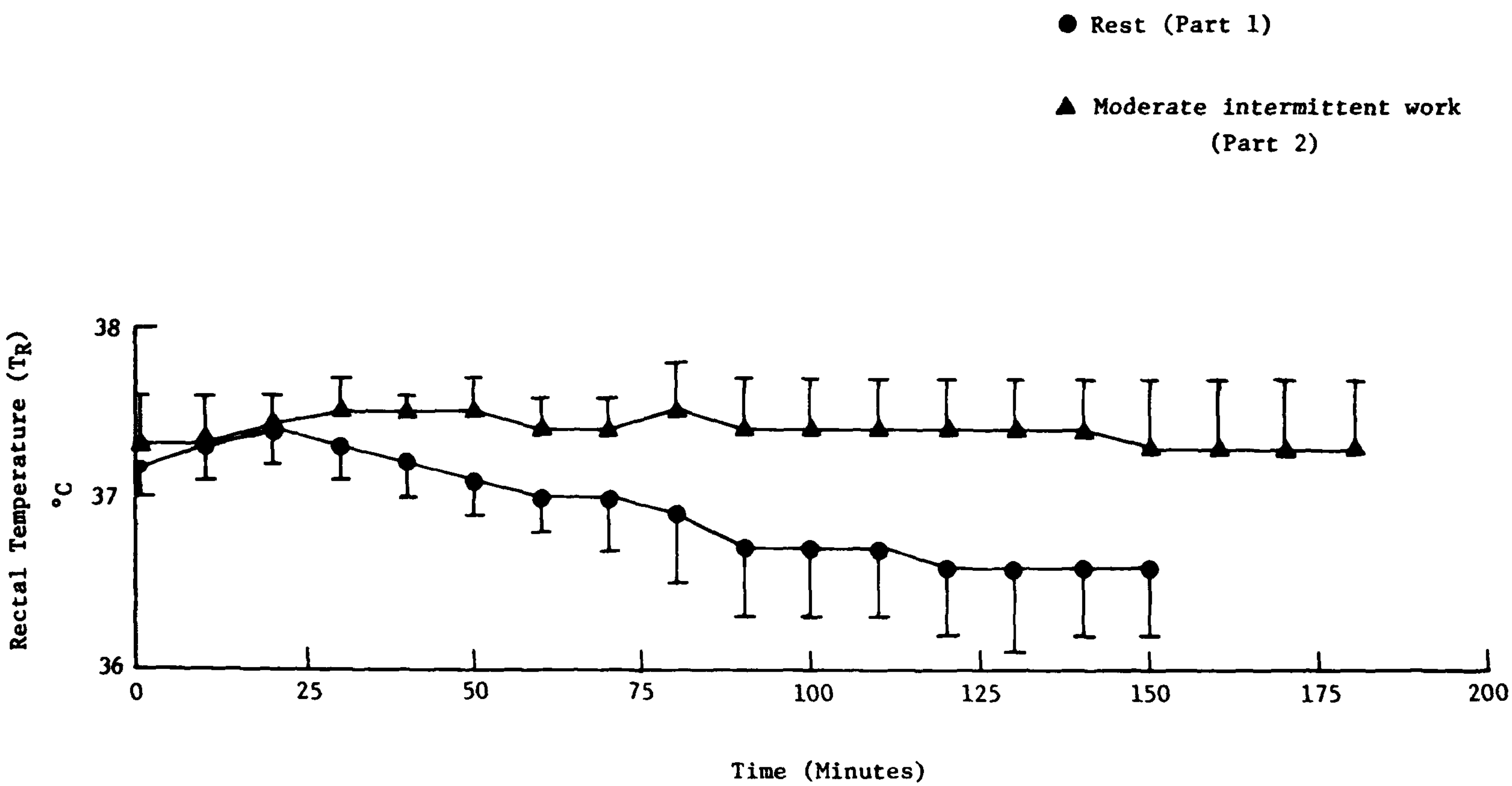
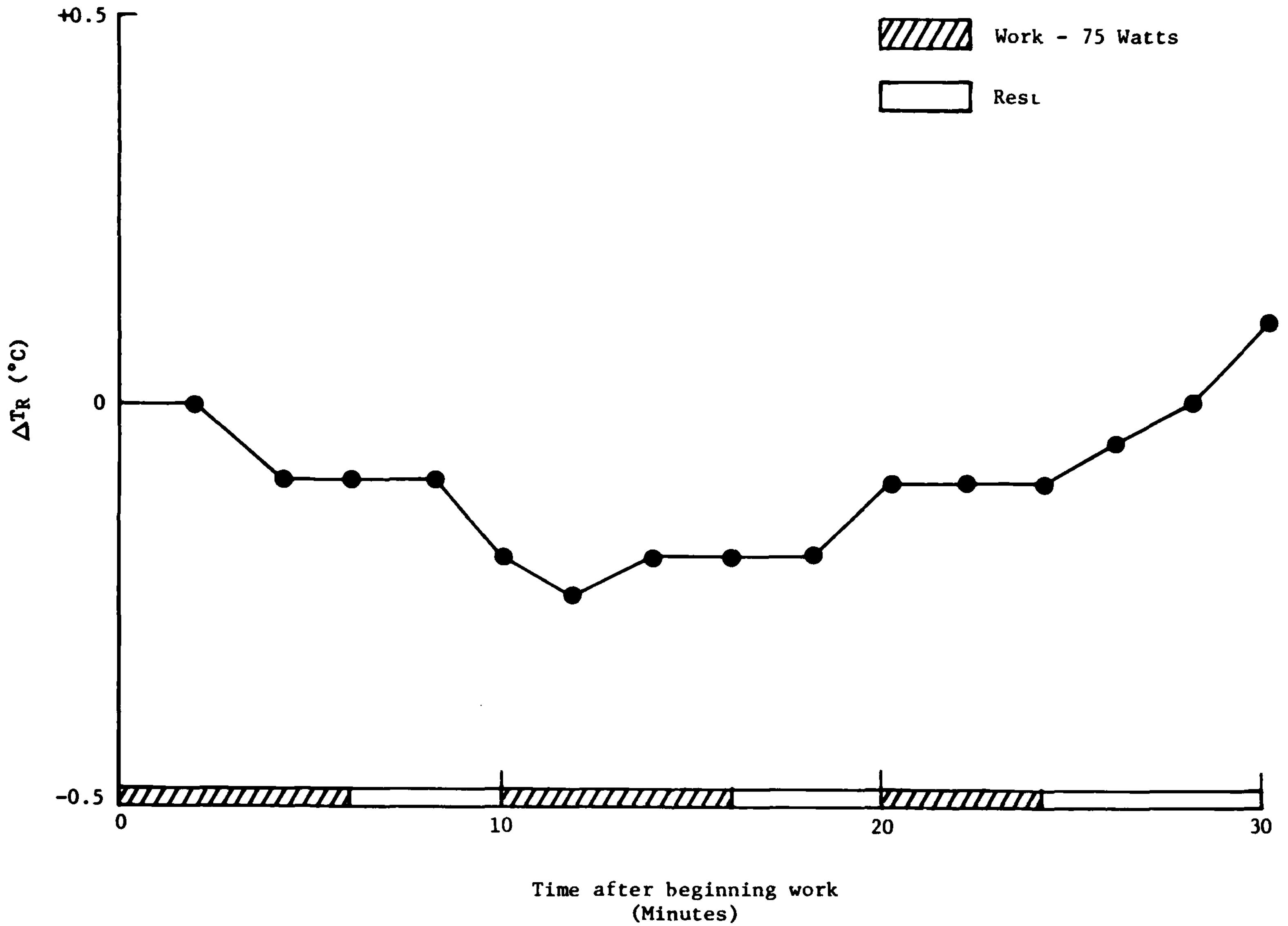


FIGURE 7: Rectal Temperature (T_R) vs Time at 70 FSW and 35°C water



Change in Rectal Temperature (ΔT_R) vs Time in Cold Divers Attempting Rewarming With Intermittant Leg Exercise While Wearing DTP Passive System in 35°C water.